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EARTH GROUND SYSTEM DESIGN AND EVALUATION.(U)
JAN 79 J D RILEY

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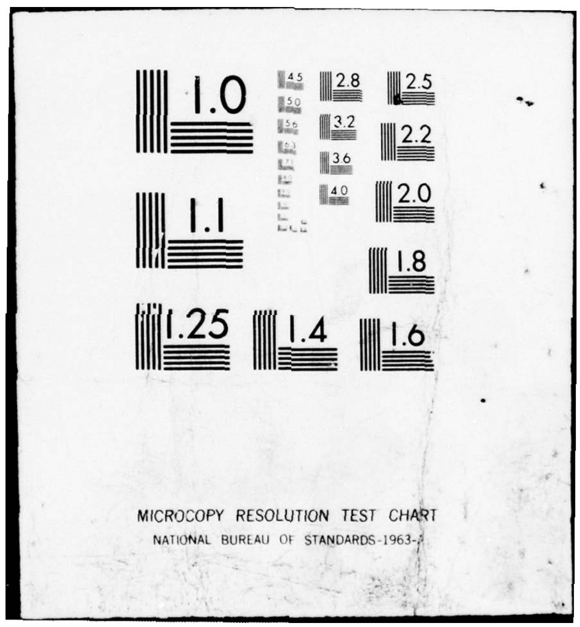
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Report No. FAA-RD-78-156

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EARTH GROUND SYSTEM DESIGN AND EVALUATION

JOHN D. RILEY

JANUARY 1979

FINAL REPORT

Prepared for

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
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16. Abstract

Model K2-10 ground rods were installed, tested, and evaluated with copper-clad steel (CCS) and CCS salt-enhanced (CCSS) rods at field sites and the National Aviation Facilities Experimental Center (NAFEC) for comparison and determination if they meet the manufacturer's specifications in high-, medium-, and low-resistivity soils under arid and wet conditions through a year of seasonal change.

It was determined at most sites that the XIT-rod-to-earth impedance remained lower than the CCS and CCSS rods under the above conditions, although seasonal impedance variations did exist. XIT rod earth impedance remained well above 4 ohms at most sites. XIT rod installation costs were greater, and unit costs were much greater than CCS and CCSS rods.

The engineering approach used herein may be a useful guide for engineering ground systems at field facilities.

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METRIC CONVERSION FACTORS

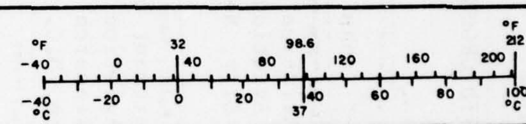
Approximate Conversions to Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.

Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



PREFACE

Acknowledgement is given XIT Company for permission to use company-provided technical specifications in this report.

Acknowledgement is also expressed to personnel at each of the test site locations for their cooperation in collecting data for this report.

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INTRODUCTION

PURPOSE.

This report describes the installation, test, and analysis of results of model K2-10 XIT ground rod, procured from the XIT Rod Company and installed at the following six sites: the National Aviation Facilities Experimental Center (NAFEC), Atlantic City, New Jersey; Wildwood, New Jersey, remote center air-ground facility (RCAG); Chesterfield, South Carolina, very high frequency omnirange (VOR); Beaumont, Texas, airport surveillance radar (ASR); El Paso, Texas, ASR; and Phoenix, Arizona, H Marker, between October 28, 1975, and January 20, 1978.

BACKGROUND.

Prior to solid state electronics, a ground rod impedance to earth of 25 ohms was sufficient protection for personnel and high-current vacuum tube electronic equipment. Since the introduction of solid state electronics, it has been realized that ground rod impedance to earth of 5 ohms or less is required for electronic equipment protection. This requirement is due to the low voltage and current capacity of solid state electronic equipment.

Early in 1974, several Federal Aviation Administration (FAA) facilities began installation of XIT rods and have since attained a measure of success with them. Late in 1975, FAA Headquarters Research and Development requested that NAFEC conduct tests to validate the manufacturer's specification.

DISCUSSION

DESCRIPTION.

The model K2-10 XIT rod in figure 1 is a type K copper tube, 10 feet long, 2 1/8 inches outer diameter, and a wall thickness of 0.083 inch. It contains metallic salts with spun glass inside each end where holes have been provided behind the capped ends. The materials within the tube absorb the external atmospheric moisture through the top entry holes where it is chemically converted to an electrolytic and by gravity enters the soil. The XIT Rod Company manufactures four different patented rods all of the same material, diameter, and wall thickness. The difference in these rods are their 8-, 10-, and 20-foot lengths or the L shaped rod which is used in areas where bedrock is close to the earth's surface.

INSTALLATION.

The installation procedure for the XIT rod is to auger a hole to the XIT rod length, insert the rod into the hole (insure that the shipping tape has been removed from over the XIT rod holes), pour in sufficient salt to cover the bottom holes, pour several gallons of water into the hole to cover the bottom rod holes, back fill the hole with earth, and tamp. It should be noted that the rod's upper holes are to be exposed to the outside air in order that it may function properly.

TEST DESIGN.

The established procedure was to compare the XIT-rod-to-earth impedance

with those of a copper-clad steel (CCS) rod and a CCS rod centered in a salt ring (CCSS) for at least a 15-month period. The tests were performed in various soil resistivities under predominately moist or dry conditions. Six sites were selected under the following conditions:

1. Low soil resistivity (up to 300 meter-ohms) with relatively high rainfall.

2. Medium soil resistivity (300 to 600 meter-ohms) with relatively high rainfall.

3. High soil resistivity (greater than 600 meter-ohms) with relatively high rainfall.

4. Low soil resistivity with relatively low rainfall.

5. Medium soil resistivity with relatively low rainfall.

6. High soil resistivity with relatively low rainfall.

Weather data were obtained from the Atlantic City Weather Service concerning average yearly temperature and rainfall throughout the nation. In addition, a Federal Communications Commission (FCC) estimated conductivity (reciprocal of resistivity) map (figure 2) was obtained for the purpose of determining prospective FAA test locations. Soil resistivity data on specific soils within the areas of possible interest were obtained from each of the local county agriculture departments. It should be noted that the resistivities at each of these locations were to depths less than 10 feet. To further insure success in site selection, earth resistivity measurements were made at each of the potential sites with a hand-cranked Biddle Megger Null Balance Earth Tester model 63220 (figure 3). Unfortunately, these measurements were not conducted at identical temperature and moisture conditions at all locations due to travel difficulties.

These measurements, as shown in figure 4, were made at 10-foot depths (length of each test ground rod) in three or more different locations, in an equilateral triangular fashion 30 feet apart. The purpose of the 30-foot triangular spread between ground rods was to avoid interaction between rods, and to attempt to attain equal and uniform resistivity for each ground rod.

A 15-month data collection period was established to verify and compare the XIT Rod Company's specification impedance-time curve with those of the CCS and CCSS rods. It can be seen in figure 5, that several months of this period were required for the XIT rod to chemically react with the earth before the impedance to earth averages 4.5 ohms. The 12 remaining months were established to determine the effects of seasonal temperature changes on the test ground rod impedance to earth (figures 6 through 11).

During the above-mentioned tests, a modified XIT rod test was conducted at NAFEC. This effort was made to determine if the XIT-rod-to-earth impedance could be further reduced and remain so during the 15-month test period. This XIT rod was modified with additional 1/4-inch holes 1 foot apart along the length of the rod. It was installed and tested in the same fashion and test area as the standard XIT rod. Figure 11 gives data results.

CERTIFICATION.

The XIT rod had undergone corrosion tests by Underwriters Laboratories and granted a listing under UL467J. These tests show that the XIT rod is less susceptible to corrosion effects than the standard CCS rods with direct current (d.c.) voltage applied for periods of 6 months and 1 year.

THEORY.

Because of the distributed nature of the earth volume into which electrical energy flows, the resistance to earth is defined as the resistance in ohms between the point of connection and a very distant point on the earth. Resistance to current flow through a ground rod depends on (a) resistance of the ground rod and connections to it, (b) ground rod and earth contact resistance, and (c) resistance of the surrounding earth (figure 12).

In table 1, the resistivity of the various metallic compounds may be determined by obtaining the reciprocal of their relative conductivities. If the size and cross-sectional areas of these materials are large, their resistances will be negligible. It should be noted that copper and silver are the two highest conductivity materials.

The contact resistance of a ground rod to earth depends on the rod surface area contact with the soil. Corrosion has little effect on contact resistance, providing it has not corroded to the extent of reducing the length of the rod.

The resistivities of various soils may be seen in table 2. Soil resistivities also vary according to moisture and temperature, as shown in table 3 and figure 13. Soil resistivity can be further reduced when salt is added as shown in figure 13.

The resistance of a rod is directly affected by changes in the length of the rod and by the logarithm of the length. Changes in the diameter only show up as slight changes in the logarithm of the length. Figures 14 and 15 show the measured changes in resistance that occur with rod length and rod diameter. It is evident that effects of rod length do predominate over the effects of rod diameter.

Soil resistivities may be obtained from (1) the FCC Conductivity Charts, (2) United States (U.S.) Department of Agriculture Soil Survey Reports of counties of interest, and (3) field measurements. The FCC Conductivity Charts are appropriate for locating general soil conductivity data in a region, but are not accurate for a specific area.

The U.S. Department of Agriculture (USDA) Soil Survey Report contains aerial photograph maps and tables of all the soil types within a specific county. A location can be pinpointed on the aerial photograph map, and the soil type outlined on it. The tables reveal all the soil particulars including conductivity and/or resistivity at various depths. These measurements, however, do not necessarily reflect the specific point that may be of interest.

Field measurements with a Megger Earth Tester provide the most accurate method of determining earth resistivity of a specific point. The other two above-mentioned methods are of value in the attempt to locate a low-resistivity area.

Soil resistivity can be expressed as $\rho = 2\pi AR$, where ρ is the average

TABLE 1. RELATIVE CONDUCTIVITY OF COMMON METALS

Metal	Relative Conductivity (g_r)	Comments
Alfenol	.011	
Beryllium	.377	
Brass	.442	66% Cu, 34% Zn
Cadmium	.230	
Chromax	.017	15% Cr, 35% Ni, 50% Fe
Chromium	.663	
Cobalt	.177	
Constantan	.039	55% Cu, 45% Ni
Copper	1.000	Commercial annealed
Gold	.707	
HyMu80	.030	80% Ni, 20% Fe
Iron, Pure	.178	Annealed
Iron, Swedish	.172	
Iron, cast	.057	
Kovar A	.006	29% Ni, 17% Co, 0.3% Mn, 53.7% Fe
Lead	.079	
Magnesium	.387	
Manganin	.039	84% Cu, 12% Mn, 4% Ni
Monel Metal	.041	67% Ni, 30% Cu, 1.4% Fe, 1% Mn
Mumetal	.034 -.069	71-78% Ni, 4.3-6% Cu, 0-2% Cr, bal. Fe
Nickel	.250	
Nickel-silver	.062	64% Cu, 18% Zn, 18% Ni
Palladium	.160	
Permalloy	.038	45% Ni, 55% Fe
Permendure	.066	50% CO, 1-2% V, bal. Fe
Platinum	.164	
Rodium	.338	
Rhometal	.019	36% Ni, 64% Fe
Sendust	.022 -.029	10% Si, 5% Al, 85% Fe (cast)
Silver	1.064	
Steel	.078 -.133	0.4%-0.5% C, bal. Fe
Steel, manganese	.025	13% Mn, 1% C, 86% Fe
Steel, silicon	.034	4% Si, 96% Fe (hot rolled)
Steel, stainless	.019	0.1% C, 18% Cr, 8% Ni, 73.9% Fe
Supermalloy	.029	79% Ni, 5% Mo, 16% Fe
Tin	.151	
Titanium	.036	
Tungsten	.315	
Zinc	.287	

TABLE 2. RESISTIVITY VALUES OF EARTHING MEDIUMS

Medium	Resistivity Minimum (ohm-cm)	Resistivity Average (ohm-cm)	Resistivity Maximum (ohm-cm)
Surface soils, loam, etc.	10^2		5×10^3
Clay	2×10^2		10^4
Sand and gravel	5×10^3		10^5
Surface limestone	10^4		10^6
Limestones	5×10^2		4×10^5
Shales	5×10^2		10^4
Sandstone	2×10^3		2×10^5
Granites, basalts, etc.		10^6	
Decomposed gneisses	5×10^3		5×10^4
Slates, etc.	10^3		10^4
Fresh Water Lakes		2×10^4	2×10^7
Tap Water	10^3		5×10^3
Sea Water	20	10^2	2×10^2
Pastoral, low hills, rich soil, typical of Dallas, Texas; Lincoln, Nebraska areas		3×10^3	
Flat country, marshy densely wooded typical of Louisiana near Mississippi River	2×10^2	10^4	
Pastoral, medium hills and forestation, typical of Maryland, Pennsylvania, New York, exclusive of mountainous territory and seacoasts		2×10^4	

TABLE 2. RESISTIVITY VALUES OF EARTHING MEDIUMS (Continued)

Medium	Resistivity Minimum (ohm-cm)	Average (ohm-cm)	Maximum (ohm-cm)
Rocky soil, steep hills, typical of New England	10^3	5×10^4	10^5
Sandy, dry, flat, typical of coastal country	3×10^4	5×10^4	5×10^5
City, industrial areas		10^5	10^6
Fills, ashes, cinders, brine, waste	6×10^2	2.5×10^3	7×10^3
Clay, shale, gumbo, loam	3×10^2	4×10^3	2×10^4
Same--with varying proportion of sand and gravel	10^3	1.5×10^4	10^5
Gravel, sandstones, with little clay or loam, granite	5×10^4	10^5	10^6

TABLE 3. APPROXIMATE SOIL RESISTIVITY

Type of Soil	Resistivity (ohm-m)	(ohm-cm)	(ohm-ft)
Wet Organic Soil	10	10^3	33
Moist Soil	10^2	10^4	330
Dry Soil	10^3	10^5	3,300
Bedrock	10^4	10^6	33,000

soil resistivity to depth A in centimeter-ohms, and R is the Megger earth tester reading in ohms. In table 4, each test site name appears in the far left column. To the right of this column are the meter readings taken at each of these sites at 2-foot and 10-foot depths. It should be noted that at Beaumont an additional 3-foot depth reading was made to see if the soil resistivity progressively reduced between 2 and 10 feet. Additional readings were not made due to limited time. At Chesterfield, South Carolina, 30-foot readings were made after 10-foot readings appeared too high. It was discovered that the resistivity remained approximately the same at 30 feet as it was at 10 feet.

Ground rod resistance to earth can be expressed as $R = \left(\frac{\rho}{2\pi L}\right)\left(\ell n \frac{4L}{a} - 1\right)$, where ρ is the soil resistivity in centimeter-ohms, L is the length of the ground rod in centimeters, and a is the diameter of the ground rod in centimeters. In table 4 it may be seen that ground rod resistances to earth were computed by using the earth measurements at various depths at all sites. The dimensions of the ground rods used in these computations were standard 10-foot length, 5/8-inch-diameter CCS rods. It should be noticed in table 4 that the average computed ground-rod-to-earth resistance is compared with the average actual measurement for each test location. It should also be noted that the average measured resistivity is compared with the FCC chart and the USDA resistivities for each test site.

Monthly ground-rod-to-earth resistance measurements with temperature and moisture can be seen in table 5. Unfortunately, the test team had difficulty in obtaining more data from Chesterfield, South Carolina, due to the lack of an earth tester for these monthly measurements. It should also be noticed that the measurements for Phoenix, Arizona, dropped to zero through the later half of this study. This condition is totally unexplainable, since several calibrated instruments were used to insure confidence in these measurements. The average measurement for Phoenix CCS rod would certainly have been higher than 49 ohms had this condition not appeared.

A plot of the measurements in table 5 may be seen in figures 6 through 10 for each test site. These plots compare each type of ground rod resistance to earth over a time period.

RESULTS

JEFFERSON COUNTY AIRPORT, BEAUMONT, TEXAS.

In table 5 and figure 6, it can be seen that the average CCSS rod resistance of 2.2 ohms to earth was twice as high as the XIT rod resist= ance of 1.1. In fact, the standard CCS rod average resistance of 6.9 was approximately six times the XIT rod resistance. The Morey-type soil is of a gumbo texture where a CCS rod can be pushed into the earth but next to impossible to remove due to a vacuum created. The ground rod bond to the earth was excellent. The XIT rod was hand augered into the earth by FAA employees. The average rainfall is 55.21 inches, and the average temperature is between 22° Fahrenheit (F) and 98° F. The soil resistivity is 9 to 19 meter-ohms at 9- to 12-foot

TABLE 4. EARTH RESISTIVITY AND GROUN
COPPER-CLAD STEEL GROUND

	Meter Readings in Ohms at 2-Foot Depth Except Where Indicated	Meter Readings in Ohms at 10-Foot Depth	Resistivity Meter-Ohms at 2-Foot Depth Except Where indicated	Resistivity Meter-Ohms at 10-Foot Depth	Average 2-Foot Depth Resistivity Meter-Ohms Except Where Indicated	Average 10-Foot Depth Resistivity Meter-Ohms	FCC Chart Resistivi Meter-Ohm
BEAUMONT TX.	2.63 (3)	0.45	15.11 (3)	8.62	15.11 (3)	9.19	33.33
Earth resistivity	5.09	0.48	19.5	9.19	18.68		
between 0-300	5.0	0.43	19.15	8.23			
meter-ohms and	5.4	0.52	20.68	9.96			
high rainfall	4.4	0.49	16.85	9.38			
	4.5	0.51	17.24	9.77			
EL PASO, TX.	20.3	3.21	77.75	61.98	70.99	61.91	125.0
Earth resistivity	19.8	3.4	75.84	65.11			
between 300-600	19.5	3.08	74.69	58.99			
meter-ohms and	20.3	3.15	77.75	60.33			
low rainfall	13.9	3.6	53.24	68.94			
	17.4	2.93	66.65	56.11			
WILDWOOD, N.J.	470	20	1,800.21	383.02	1,445.19	316.95	250.0
Earth resistivity	680	17	2,604.56	224.07			
between 300-600	270	13	1,034.16	248.96			
meter-ohms and	295	23	1,129.92	440.48			
high rainfall	310	20	1,187.37	383.02			
	240	11.6	919.26	222.15			
PHEOENIX, AZ.	233	50.8	892.44	972.88	888.61	773.11	66.67
Earth resistivity	231	56.3	884.78	1,078.21			
between 600-1100		34.5		660.71			
meter-ohms and		32.4		620.5			
Low rainfall		30.2		578.36			
		37.7		722.0			
NAFEC, N.J.	463	184	1,773.4	3,523.81	1,886.39	3,590.84	250.0
Earth resistivity	522	191	1,999.38	3,657.87			
above 600 meter-							
ohms and high							
rainfall							
CHESTERFIELD, S.C	437 (30)	1,430	25,107.16 (30)	27,386.0	29,645.98 (30)	29,971.5	500.0
Earth resistivity	595 (30)	1,700	34,184.8 (30)	32,557.0			
above 600 meter-							
ohms and high							
rainfall							

OUND ROD CALCULATIONS FOR
D RODS 5/8-INCH DIAMETER

Chart ...tivity ...-Ohms	Computed Ground Rod Resistance in Ohms	Average Measured 10-Foot Ground Rod Resistance in Ohms	U.S. Department of Agriculture Soil Survey Data For Each Locality
3.33	19.68 (2) 11.68 (3) 2.71 (10)	6.9	Morey soil, clay and silty or gumbo texture. Average rainfall 55.21 inches. Average temperature 22°F-98°F. Resistivity is 9-19 meter-ohms at 9 to 12 feet depth.
5.0	74.77 (2) 18.24 (10)	20.7	Hueco-wink soil which is a fine loam sand and moist 80 inches below surface. Average rainfall 7.89 inches. Average temperature 49.9°F-77.2°F. Conductivity is less than 2 mmhos/cm or 5 meter-ohms down to 80 inches depth.
0.0	1522.97 (2) 93.4 (10)	146.0	Hammonton sandy loam soil with water table 5 feet below surface. Average rainfall 43 inches, average temperature 10°F-94°F. Resistivity is 10 to 50 meter-ohms to 80 inches depth.
6.67	935.97 (2) 227.83 (10)	49.0	Alluvial soil which is a very sandy loam and dry below 10 feet. This soil prevails along riverbeds in this region. Average rainfall 6-8 inches. Rain is excessive at times. Average temperature 40°F-100°F. No Resistivity or conductivity measurements given.
0.0	1986.92 (2) 1058.21 (10)	450.0	Quartzipsamments soil which is coarse sand with quartzrose gravel. Resistivity is greater than 50 meter-ohms down to 60 inch depth.
0.0	8832.52 (10) 3479.08 (30)	> 10000.0	Typic quartzipsamments lakeland soil which is coarse grain sand 100-200 feet to rockbed. Average rainfall 55 inches. Average temperature 66°F. No resistivity or conductivity measurements given.

2

TABLE 5. MONTHLY GROUND ROD RESISTANCE MEASUREMENT

			1975	1976											1976	1977					
	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APR.	MAY	JUN.
BEAUMONT, TX											16	14	7	5	22	24		29		6	9
XIT Rod											1.75	1.2	1.3	1.1	0.2	0.7	0.7	1.0		1.2	1.6
CCS Rod											3.08	3.0	3.7	6.1	7.6	6.4	6.7	10.0		6.9	7.8
CCSS Rod											3.37	2.6	2.6	2.3	2.0	2.0	1.8	2.2		2.3	2.0
Temperature (°F)											89°	90°	65°	65°	42°	51°	60°	73°		80°	84°
Soil Moisture											moist	moist	dry	wet	wet	wet	dry	wet		moist	dry
EL PASO, TX.											17		1	1	2	4	9	2	11	2	1
XIT Rod											9.04		8.1	8.4	9.07	9.4	9.4	9.4	9.6	9.4	9.9
CCS Rod											9.01		17.5	19.0	18.5	21.0	22.5	21.0	21.0	20.0	22.0
CCSS Rod											21.9		21.4	23.0	23.0	36.0	16.0	13.0	12.0	12.0	14.0
Temperature (°F)											95°		69°	64°	39°	56°	48°	50°	58°	68°	91°
Soil Moisture											dry		moist	moist	moist	dry	moist	dry	dry	dry	dry
WILDWOOD, N.J.											9	17	7	9	10	12	10	10	15	16	14
XIT Rod											42.0	41.5	38.0	45.0	50.0	58.0	76.0	60.5	65.0	64.2	59.0
CCS Rod											150.0	140.0	135.0	153.0	180.0	360.0	135.0	130.0	130.0	130.0	113.0
CCSS Rod											183.0	50.5	45.0	45.0	50.0	67.0	78.0	81.0	87.0	90.0	82.0
Temperature (°F)											73°	86°	76°	40°	48°	17°	46°	50°	60°	80°	70°
Soil Moisture											wet	wet	dry	moist	moist	ice	ice	moist	dry	dry	moist
PHOENIX, AZ.											19	21		18	20	13	17	15	12	26	
XIT Rod											22.0	28.0	22.0	22.0	21.0	28.0	31.0	31.0	31.0	22.0	
CCS Rod											69.0	68.0	63.0	64.0	80.0	78.0	88.0	88.0	93.0	93.0	
CCSS Rod											50.3	43.5	42.0	44.0	64.0	56.0	64.0	64.0	66.0	66.0	
Temperature (°F)											103°	98°	90°	86°	67°	50°	86°	72°	86°	71°	
Soil Moisture											dry	dry	dry	dry	dry	dry	dry	dry	dry	dry	
ATLANTIC CITY, N.J.	28	1	6	6	8	22	6	21	24		3	14	5	29	3	4	10	10	14	3	3
XIT Rod	408.0	297.0	213.0	110.0	172.0	221.0	210.0	212.0	187.0		222.0	210.0	210.0	210.0	260.0	390.0	400.0	410.0	400.0	410.0	422.0
CCS Rod		425.0	442.0	640.0	540.0	541.0	495.0	426.0	394.0		413.0	350.0	350.0	390.0	445.0	520.0	670.0	510.0	460.0	430.0	437.0
CCSS Rod			195.0	202.0	340.0	340.0	330.0	295.0	280.0		313.0	215.0	270.0	270.0	400.0	430.0	685.0	570.0	570.0	620.0	600.0
Modified XIT Rod					240.0	129.0	120.0	116.0	110.0		125.0	110.0	101.0	100.0	100.0	104.0	115.0	120.0	110.0	110.0	108.0
Temperature (°F)	80°	35°	30°	28°	23°	70°	61°	80°	78°		73°	86°	68°	55°	30°	37°	46°	50°	60°	69°	61°
Soil Moisture	dry	moist	moist	moist	ice	wet	dry	moist	dry		dry	dry	wet	wet	dry	snow	ice	moist	dry	moist	dry
CHESTERFIELD, S.C.						24	30	26					7		7						
XIT Rod						2740.0	2500.0	2200.0					2200.0		2100.0						
CCS Rod						4380.0	>10k	>10k					>3k		>3k						
CCSS Rod						>10k	2700.0	1900.0					1050.0		950.0						
Temperature (°F)						61°	75°	62°					78°		77°						
Soil Moisture						dry	dry	wet					dry		moist						

ENTS IN OHMS

JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	1977 DEC.	1978 JAN.	HIGH	LOW	AVG.	REMARKS
9	7	8			14	16					
1.6	1.1	1.2			1.2	1.2		1.75	0.2	1.1	February 1977 readings were
7.8	7.2	10.0			10.2	8.2		10.2	3.0	6.9	made March 1, 1977, and March
2.0	2.0	1.8			1.8	2.0		3.37	1.8	2.2	1977 readings were made March
84°	84°	94°			72°	52°					29, 1977.
dry	dry	moist			dry	wet					
1		1	1	4	1	12	6				
9.9		13.0	12.0	12.0	12.0	14.0	16.0	16.0	8.1	10.7	Additional salt enhancement was
22.0		22.0	20.0	20.0	20.0	23.0	24.0	24.0	17.5	20.7	made to the CCSS rod to drop
14.0		15.0	11.0	10.0	12.0	12.0	12.0	36.0	10.0	16.5	resistance below the CCS rod
91°		94°	91°	67°	63°	63°	53°				on February 9, 1977.
dry		dry	dry	wet	dry	dry	wet				
14	11	11	12	5	16						
59.0	60.0	77.0	71.0	71.0	62.0			77.0	38.0	59.0	
13.0	96.0	105.0	113.0	130.0	132.0			360.0	96.0	146.0	
82.0	50.0	90.0	93.0	99.0	122.0			183.0	45.0	82.0	
70°	75°	89°	75°	72°	64°						
moist	dry	moist	dry	dry	moist						
	20	19	6	13	21	13					
	0.0	0.0	0.0	0.0	0.0	0.0		31.0	0.0	16.1	October 1976 readings were made
	0.0	0.0	0.0	0.0	0.0	0.0		93.0	0.0	49.0	November 2, 1976, and November
	0.0	0.0	0.0	0.0	0.0	0.0		66.0	0.0	35.0	1976 readings were made November
	98°	109°	101°	86°	74°	69°					18, 1976.
	dry	dry	dry	dry	dry	dry					
3	22	6	15	4							
22.0	428.0	383.0	375.0	377.0				428.0	110.0	297.0	October 1976 readings were made
37.0	396.0	361.0	368.0	358.0				670.0	350.0	450.0	on the 5th and 28th. No readings
0.0	540.0	486.0	539.0	552.0				685.0	195.0	411.0	were made on November 1976.
8.0	92.0	90.0	86.4	87.9				240.0	86.4	114.0	
61°	81°	84°	70°	66°							
dry	dry	wet	dry	moist							
								2740.0	2100.0	2348.0	The last two readings were made
								>10k	4300 0	>10k	with a Vibroground earth tester
								>10k	950.0	3320.0	which has a 3k-ohm maximum scale.
											The first three readings were made
											with a NAFEC Biddle earth tester
											ohm maximum scale.

1

2

depths. Our resistivity measurement for this site averaged 2.71 meter-ohms at 10-foot depth. During the 15-month period of varying temperature and precipitation, the resistance to earth change of the CCSS rod was only 0.02 ohms higher than the XIT rod's 1.55 ohms. In fact, the CCS rod resistance change was only 7.2 ohms for the same period.

In table 6, it can be seen that the average ground-rod-to-earth resistance of the XIT rod (1.1 ohms) was half that of the CCSS rod (2.2 ohms) and a sixth of that of the CCS rod (6.9 ohms). The resistance variation during the entire test period for the XIT rod (1.55 ohms) was almost the same as that of the CCSS rod (1.57 ohms) and about a fifth of that of the CCS rod (7.2 ohms).

EL PASO AIRPORT, EL PASO, TEXAS.

As indicated in table 5 and figure 7, it was discovered that an insufficient amount of salt was placed around the CCSS rod. Additional salt was added around this rod on February 9, 1977. If the CCSS rod measurements were considered beginning at this date, the average ground-rod-to-earth resistance would be 12.63 ohms, and the resistance variation would be 6 ohms instead of 26 ohms. The XIT rod average ground-rod-to-earth resistance was 10.7 ohms, and the resistance variation was 7.9 ohms. The standard CCS rod average ground-rod-to-earth resistance was 20.7 ohms, and the resistance variation was 6.5 ohms.

It can be seen that if the revised CCSS rod measurement readings were considered, then the CCSS and the CCS rods resistance variations were less than the XIT rod. The CCSS rod and the XIT rod average resistance to earth would be only 2-ohms difference, while the CCS rod is twice the resistance of the XIT rod.

The Hueco-Wink soil is a fine loam sand, and a CCS rod can be easily hammered into the soil. The XIT rod installation cost was $45.00 and required heavy equipment for installation in this soil. The average rainfall is 7.89 inches, and the average temperature is between 49.9° F and 77.2° F. The soil resistivity is greater than 5 meter-ohms to a 6.67-foot depth.

In table 6, it can be seen that the average ground-rod-to-earth resistance of the XIT rod (10.7 ohms) was four-fifths of the CCSS rod (12.6 ohms) and half of the CCS rod (20.7 ohms). The resistance variation during the entire test period for the XIT rod (7.9 ohms) was 1.9 ohms more than the CCSS rod (6.0 ohms) and 1.4 ohms more than the CCS rod (6.5 ohms).

WILDWOOD RCAG SITE, WILDWOOD, NEW JERSEY.

In table 5 and figure 8, it can be seen that the XIT rod average ground-rod-to-earth resistance was 59 ohms, and the resistance variation was 39 ohms. The CCS rod average ground-to-earth resistance was 146 ohms, and the resistance variation was 264 ohms. The CCSS rod average ground-to-earth resistance was 82 ohms, and the resistance variation was 138 ohms. Although the CCSS rod average ground-to-earth resistance was only 28 percent higher than the XIT rod, the resistance variation was 3.5 times the XIT rod resistance variation. The CCS rod average ground-to-earth resistance was 146 ohms, and the resistance variation was 264 ohms. These readings were approximately twice the readings on the CCSS rod,

TABLE 6. GROUND ROD RESISTANCE COMPARISONS

SITE	RESISTANCE	MOD. XIT	XIT	CCSS	CCS
	Average		1.1	2.2	6.9
Beaumont	Variation		1.55	1.57	7.2
TX.	Ratio to XIT			2:1	6.3:1
	Average		10.7	12.6	20.7
El Paso	Variation		7.9	6.0	6.5
TX.	Ratio to XIT			1.2:1	1.9:1
	Average		59.0	82.0	146.0
Wildwood	Variation		39.0	138.0	264.0
N.J.	Ratio to XIT			1.5:1	2.5:1
	Average		16.1	35.0	49.0
Phoenix	Variation		31.0	66.0	93.0
AZ.	Ratio to XIT			2.2:1	3:1
	Average	114.0	297.0	411.0	450.0
NAFEC	Variation	153.6	318.0	490.0	320.0
N.J.	Ratio to XIT	0.4:1		1.4:1	1.5:1
	Average		2348.0	3320.0	>3k
Chesterfield	Variation		640.0	9050.0	
S.C.	Ratio to XIT			1.4:1	

approximately eight times the XIT rod resistance variation, and twice the XIT rod average resistance. The Hammonton soil is a sandy loam with a water table approximately 5 feet below the earth surface. The average rainfall is 43 inches, and the average temperature is between 10° F and 94° F. The soil resistivity is between 10 and 50 meter-ohms to a 6.67-foot depth. The extremely high ground-rod-to-earth resistance for the CCS rod of 360 ohms was due to a severely cold winter in 1976 and 1977. The XIT rod was hand augered into the earth by NAFEC employees.

With all three ground rods about 3,000 feet from the bay and encountering ground water 5 feet below the earth surface, it can be seen in table 6 that the average ground-rod-to-earth resistance of the XIT rod (59 ohms) was three-fourths of the CCSS rod (82 ohms) and a fourth of the CCS rod (146 ohms). The resistance variation during the entire test period for the XIT rod (39 ohms) was 99 ohms less than the CCSS rod (138 ohms) and 225 ohms less than the CCS rod (264 ohms).

PHOENIX H MARKER SITE, PHOENIX, ARIZONA.

In table 5 and figure 9, it will be noticed that the average XIT rod earth-to-ground resistance is half the value of the CCSS rod and a third of the CCS rod. It is further noticed that the same is true of the resistance variations. During the eleventh month of testing, all ground rod readings dropped to zero. This phenomenon cannot be explained. This test bed is located in Alluvial soil that is very sandy loam. The average rainfall is between 6 and 8 inches but can be excessive at times. The average temperature is between 40° F and 100° F. The USDA made no resistivity or conductivity readings in this soil. The XIT rod installation cost was $60.00, and a backhoe was required instead of an auger due to the fine sandy texture of the soil.

In table 6, it can be seen that the average ground-rod-to-earth resistance of the XIT rod (16.1 ohms) was about half of the CCSS rod (35 ohms) and a third of the CCS rod (49 ohms). The resistance variation during the entire test period for the XIT rod (31 ohms) was half the CCSS rod (66 ohms) and a third of the CCS rod (93 ohms).

The last 6 months of data collection results showed zero ohms for all three test ground rods. These results are totally unexplainable, since field sector personnel calibrated three different type earth testers and got the same measurement from each instrument in the test site. One possibility for these zero readings for the last 6 months is that the water table rose due to the above-normal rainfall in the area and the location of site in a former salt riverbed area.

NAFEC, ATLANTIC CITY, NEW JERSEY.

In table 5 and figure 10, it can be seen that the modified XIT ground-rod-to-earth average resistance was 114 ohms, and the variation of resistance was 154 ohms. The standard XIT ground rod average resistance was 297 ohms, and the variation of resistance 318 ohms. The CCS rod average resistance was 450 ohms, and the variation of resistance 320 ohms. The CCSS rod average resistance was 411 ohms, and the variation of resistance 490 ohms.

It should first be noted that the modified XIT rod's average resistance and variation of resistance were less than half the resistances of the standard XIT rod. The CCSS ground rod's poor resistive performance relative to the CCS ground rod in the last 5 months of the 2-year test appears to be due to the loss of salt enhancement. All ground rods except for the modified XIT rod appear to have increase in resistance during the very cold winter of 1976-1977. It further appears that these ground rod resistances never returned to their original low summer values. It should be further noted that the modified XIT rod resistance to earth versus time plot more closely resembles the XIT rod company's standard XIT rod plot in figure 5. NAFEC's quartzipsamments soil is a coarse sand with quartzrose gravel mix. The average rainfall is 43 inches, and the average temperature is between 10° F and 94° F. The soil resistivity is greater than 50 meter-ohms to a 5-foot depth. The XIT rods were machine augered into the earth by NAFEC employees.

In table 6, it can be seen that the average ground-rod-to-earth resistance of the XIT rod (297 ohms) was 2 1/2 times the NAFEC-modified XIT rod (114 ohms), three-fourths of the CCSS rod (411 ohms), and two-thirds of the CCS rod (450 ohms). The resistance variation during the entire test period for the XIT rod (318 ohms) was twice that of the modified XIT rod (153.6 ohms), three-fifths of the CCSS rod (490 ohms), and about equal to the CCS rod (320 ohms).

In figure 11, it should be noted that the CCSS rod lost its salt enhancement during the January-February 1976 period and remained higher in resistance than the CCS rod. It should also be noted that the XIT rod resistance increased above the CCS rod during the June-July 1977 period and remained so thereafter. The modified XIT rod remained substantially lower and at steady resistance value during the entire test period. In fact, it was continuing a slightly downward resistance trend. The modified XIT rod, CCSS rod, and CCS rod resistance ratios to the XIT rod were 0.4 to 1, 1.4 to 1, and 1.5 to 1, respectively. Testing of the modified XIT rod should be continued to determine if the same favorable results can be obtained in soils in other regions of the country.

CHESTERFIELD VOR SITE, CHESTERFIELD, SOUTH CAROLINA.

Despite the poor data return, it was believed that these few data were of significant importance. Unfortunately, these data were obtained from two different earth testers with different maximum scales. The first three measurements were made with a NAFEC Biddle tester with 10,000-ohms maximum scale, and the last two measurements were made with a Southern Region's Vibroground tester with 3,000-ohms maximum scale. Assuming that the Vibroground tester's maximum scale was the same as the Biddle tester's maximum 10,000-ohm scale, the CCS rod average ground resistance would than approximate 10,000 ohms as shown in table 5 and figure 10. The XIT rod earth-to-ground average resistance was 2,348 ohms, and the variation of resistance was 640 ohms. The CCSS rod earth-to-ground average resistance was 3,320 ohms, and the variation of resistance was approximately 9,050 ohms. This test bed is located in typical quartizpsamments (Lakeland Series) soil that is of a coarse-grain sand texture down to between 100 and 200 feet to bedrock.

The average rainfall is 55 inches, and the average temperature is 66° F. The USDA made no resistivity or conductivity measurements of this soil. The XIT rod was installed by Southern Region personnel with a hand auger.

Due to the lack of funds for this project and available earth testers in the Florence, South Carolina, AFS, data collection was sparse. This was unfortunate, since the Lakeland series soil extends from Texas to Virginia and covers bedrock and has rapid permeability in the Chesterfield area. The average resistivity measurements at a 2-foot depth was 29,646 meter-ohms and 29,971 meter-ohms at a 10-foot depth.

With the small amount of data collected, it can be seen in table 6 that the average ground-rod-to-earth resistance of the XIT rod (2,348 ohms) was two-thirds of the CCSS rod (3,320 ohms). The CCS rod resistance was off the meter scale resulting in an unknown figure. The resistance variation for the entire test period for the XIT rod, 640 ohms, was much less than the CCSS rod, 9,050 ohms.

A ground grid of 20-foot XIT rods may prove a beneficial test for this type of facility ground environment, since longer ground rods further reduce ground-grid-to-earth resistance.

COST ANALYSIS.

Since XIT rods cost $141.75 each and require contractor augering equipment with labor cost up to $65, a single XIT rod installation amounts to a total cost of $206.75. By comparison, installation of 12 CCS rods at $72 interconnected with 360 feet of 3/8-inch-diameter bare copper wire at $14.40 using government labor without special installation equipment amounts to a total cost of $110.40.

In table 7, a comparison has been made of the resistance and cost of a single XIT rod for each test site versus various CCS ground grid systems. It should be noted, however, that a ground grid of XIT rods would be an excellent means of attaining a low resistance ground at sites like NAFEC and Chesterfield.

Although the XIT-rod-measured resistance appeared lower than the CCS ground grids for Phoenix, it should be noted that the earth resistivity continued decreasing to zero during the test period. The CCS ground grid computations were based on the original 773.11 meter-ohms resistivity.

The method used in deriving these computations, utilized the following formulas for a square or rectangular ground grid.

(1) The total resistance of N CCS rods.

$$R_R = \frac{.366\,\rho\, K}{NL_R} \log \frac{3L_R}{d_R}$$

(2) The total resistance of connecting wire to the ground rods.

$$R_w = \frac{\rho}{2\sqrt{4A/\pi}} + \frac{\rho}{L_w}$$

(3) The total mutual resistance of wire and rods.

$$R_{wR} = \frac{.73\rho}{L_w} \log \frac{2\,L_w}{L_R}$$

TABLE 7. RESISTANCE IN OHMS AND COST OF XIT ROD VERSUS CCS GROUND GRID

Site	Resistivity	XIT Rod Measured Resistance	R_T Rods 20 Feet Apart	R_T Rods 10 Feet Apart	R_T Rods 20 Feet Apart	R_T Rods 40 Feet Apart	R_T Rods 20 Feet Apart	R_T Rods 20 Feet Apart	R_T Rods 20 Feet Apart	R_T Rods 20 Feet Apart
Beaumont	9.19	1.1	0.5	0.5	0.3	0.3	0.2	0.2	0.1	0.1
El Paso	61.91	10.7	3.4	3.2	1.8	1.7	1.2	1.0	0.7	0.7
Wildwood	316.95	59.0	17.6	16.6	9.4	8.9	6.4	5.1	3.6.	3.6
Phoenix	773.11	16.1	42.8	40.4	23.0	21.7	15.6	12.4	8.8	8.7
NAFEC	3,590.85	297.0	198.9	187.8	106.8	100.9	72.4	57.5	40.9	40.4
Chesterfield	29,971.5	2,348.0	1,660.3	1,567.7	891.4	842.6	604.3	480.2	341.6	337.2
Parameters										
A grid area			400 ft.	400 ft.	1,600 ft.	1,600 ft.	1,600 ft.	3,600 ft.	3,600 ft.	3,600 ft.
L_W wire length			80 ft.	80 ft.	160 ft.	160 ft.	320 ft.	360 ft.	720 ft.	720 ft.
L_R rod length			10 ft.	10 ft.	10 ft.	20 ft.	10 ft.	10 ft.	10 ft.	10 ft.
D_R rod diameter			0.625 in.	0.625 in.	0.625 in.	0.625 in.	0.625 in.	0.625 in.	0.625 in.	0.625 in.
K resistance ratio			1.25	1.85	1.4	1.25	1.4	1.6	1.6	1.7
N number rods			4	8	8	4	8	12	12	16
Installation Costs		$206.75	$35.20	$67.20	$70.40	$70.40	$76.80	$110.40	$124.80	$176.80

(4) The total resistance of the ground grid.

$$R_T = \frac{R_w R_R - R_{wR}^2}{R_w + R_R - 2 R_{wR}}$$

Where ρ is the soil resistivity in meter-ohms,
A is the ground grid area in square meters,
L_w is the total length of connecting wire,
L_R is the length of each rod,
d_R is the diameter of each rod,
K is the resistance ratio (see figure 16).

See appendix for programing procedures for these computations in a TI58 or TI59 pocket calculator.

CONCLUSIONS

From the results, it is concluded that:

1. At sites where soil resistivity is low and under humid conditions, a single CCSS rod would be sufficient to maintain a low earth resistance during seasonal weather changes. If the replenishment of salt is cumbersome, then a CCS ground grid of four rods should maintain seasonal resistance changes below 5 ohms. Either method would be cheaper than an XIT rod.

2. At sites where soil resistivity is low and under dry conditions, a CCS ground grid of eight rods should maintain seasonal resistance changes below 5 ohms. The area encompassed by such a ground grid would accommodate most FAA facilities. See column 5 of table 7.

3. At sites where soil resistivity is medium and under humid conditions, a CCS ground grid of 12 rods should maintain seasonal resistance changes near 5 ohms. If a 90-square-foot area is too large, a ground grid of four XIT rods would be needed to reduce the area to a 20-square-foot area. It should be noted that the cost of the CCS ground grid would be $124.80 (see column 7 of table 7), while the XIT rod ground grid would be $570.20 excluding installation costs.

4. Since the Phoenix, Arizona, soil resistivity became reduced to some value below 773.11 meter-ohms, where even the CCS rod-to-earth resistance was zero, the average measured XIT rod-to-earth resistance value of 16.1 ohms is rather meaningless. The CCS ground grid calculations in table 7 are based on the maximum 773.11 meter-ohm resistivity. If it could be assumed that the data were meaningful, then the same conclusion could be made for sites with medium soil resistivity under humid conditions, with exception that a larger CCS ground grid would be required.

5. At sites where soil resistivities are high and under humid conditions, a ground grid of XIT rods would be more practicable, especially where area is limited.

6. In view of the excellent results obtained with the modified XIT rod (see figure 15), this type XIT rod in a ground grid would require fewer ground rods, thus reducing ground grid area and cost while still obtaining a low ground grid resistance.

RECOMMENDATIONS

From the conclusions, it is recommended that:

1. Earth resistivity measurements should be made prior to installation of facility electronic equipment.

2. Local county agriculture departments should be consulted to determine soil salinity and/or resistivity, depth of bedrock, permeability, water table, etc.

3. Computations should be made to determine whether an XIT rod, CCS rod, or CCSS rod ground grid would attain the desired earth-ground rod resistance and if the cheaper CCS rod grid system would suffice in lieu of the XIT rod grid system.

4. Consideration should be made for the use of the modified XIT rod, especially in high soil resistivity areas. Twenty-foot XIT rods should also be considered for these areas.

5. The use of XIT rods in low earth resistivity areas with high or low rainfall is questionnable, since an increased number of CCS rods in a grid could do the job at lower cost.

6. The use of XIT rods in medium earth resistivity areas is worth considering if a ground grid size is limited by the facility area.

7. The XIT rod resistance at all sites except one averaged well above the company's low claim. Its resistance variation over the test period was as large as the CCS rod at NAFEC. See table 6 and figures 10 through 15.

8. At sites with high soil resistivity, a ground grid of 20-foot-long modified XIT rods may be the solution to the ground resistance problem.

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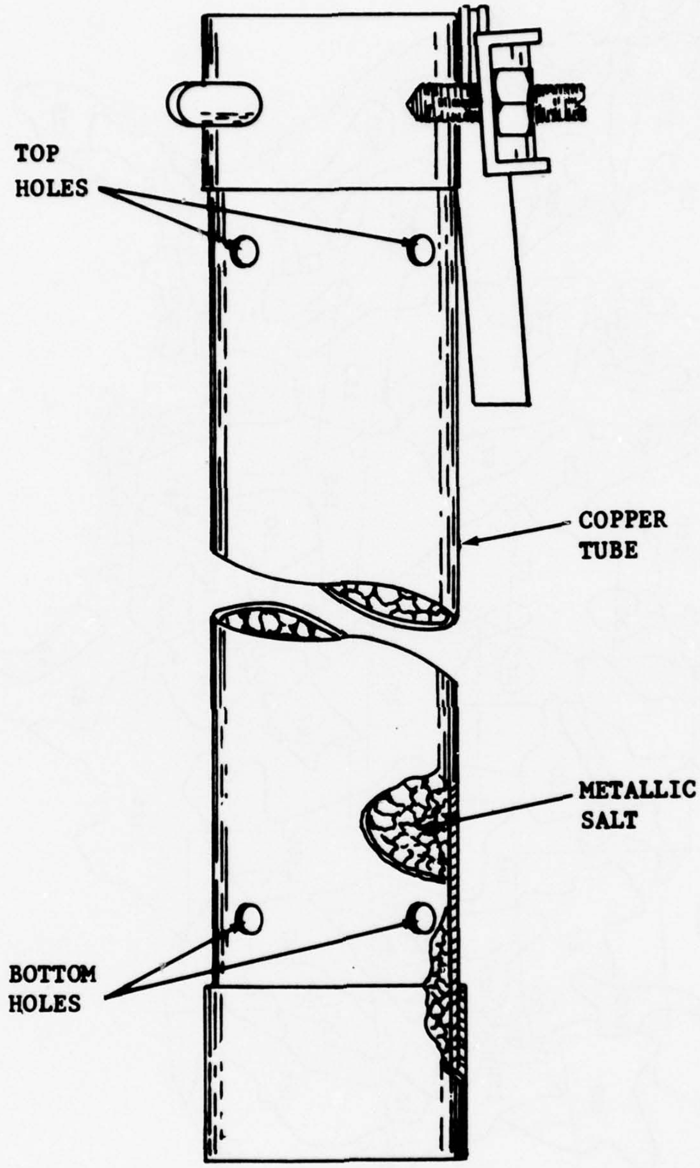
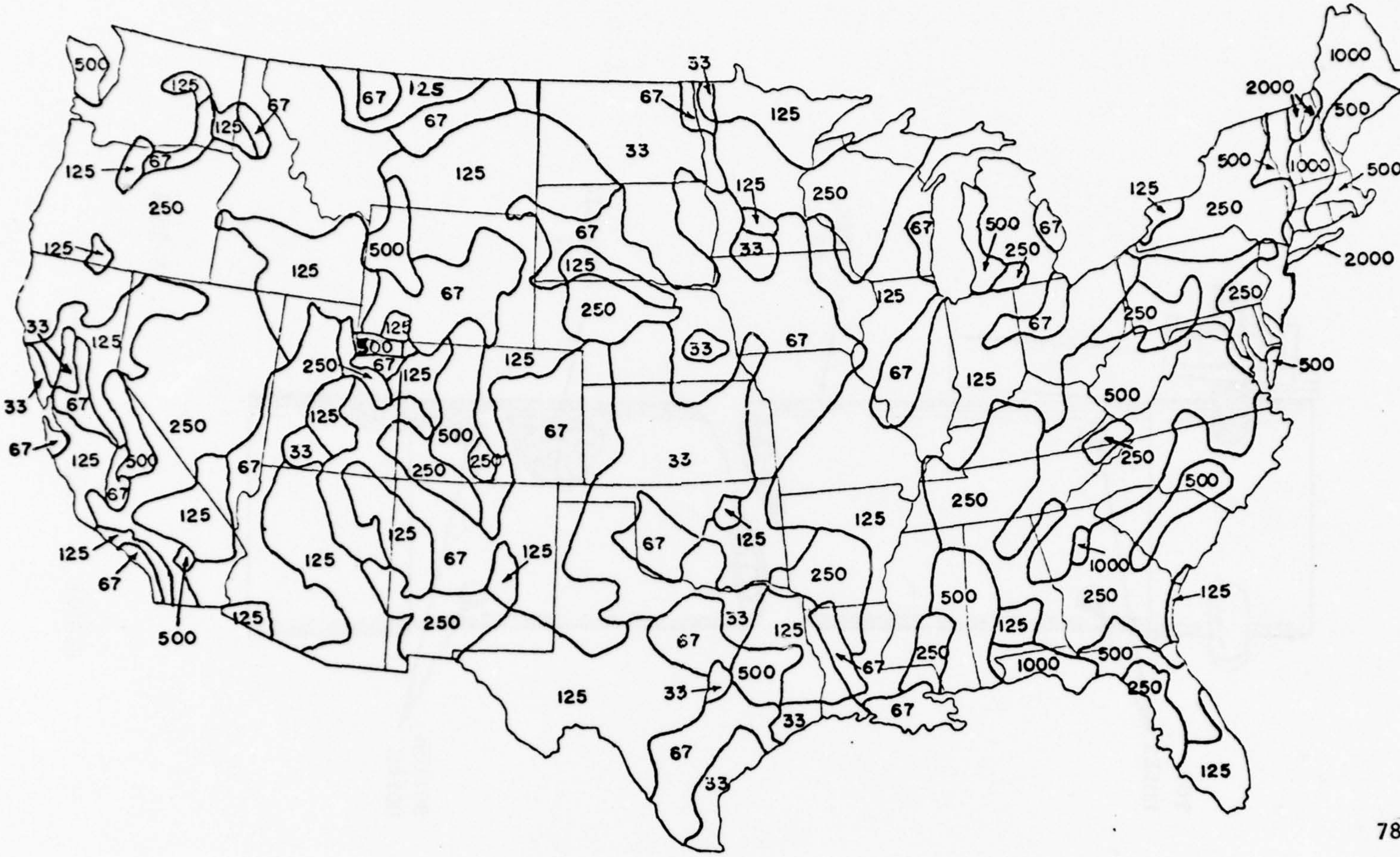


78-50-1

FIGURE 1. XIT GROUND ROD



78-50-2

FIGURE 2. ESTIMATED AVERAGE EARTH RESISTIVITY IN U.S.

FIGURE 3. BIDDLE EARTH TESTER KIT

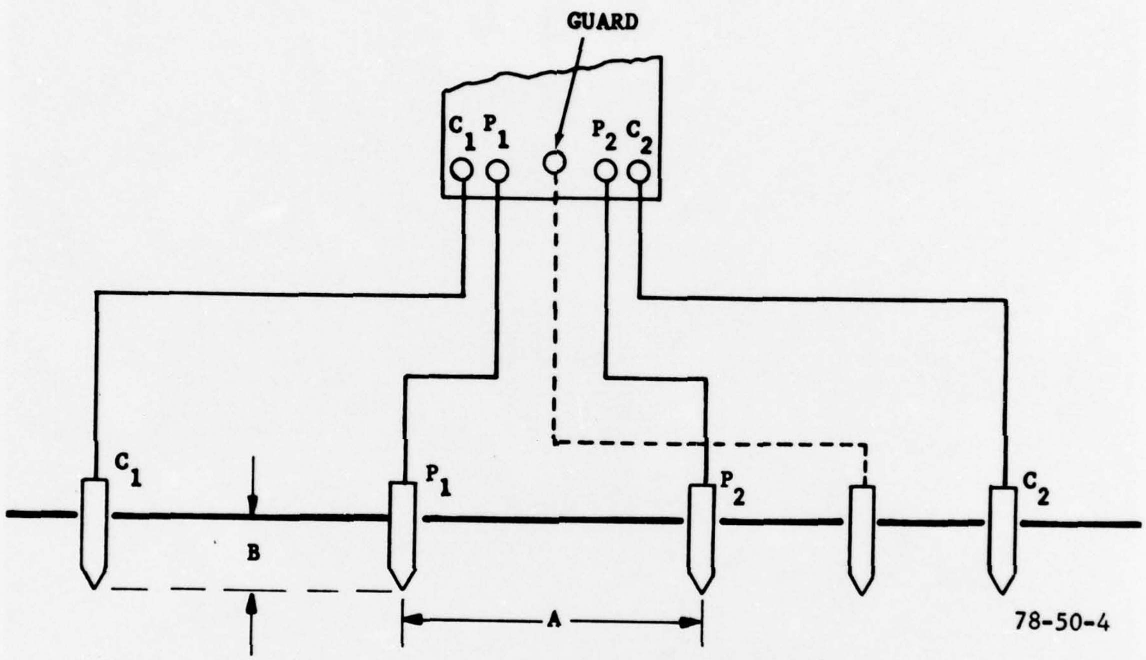
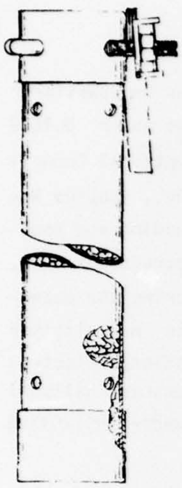


FIGURE 4. EARTH RESISTIVITY MEASUREMENT SETUP

TECHNICAL SPECIFICATIONS

Xit-Rods are used in any electric, communication, or process system, in arid or wet conditions, and their impedance to ground averages 4 ohms or less. They cost less to use than any other made or investment system because only one Xit Rod is necessary as compared to the plurality of other rods usually required. No periodic checking or adjustments are necessary.

Diameter of all models is 2-1/8" O.D.
Wall thickness = .083"
Material = Type K Copper



.K2-8 Standard model for general use 8' lengths.

.K2-10 Is recommended for installations in jurisdictions where 10' depth is minimum requirement, and in areas where a high resistivity factor is known.

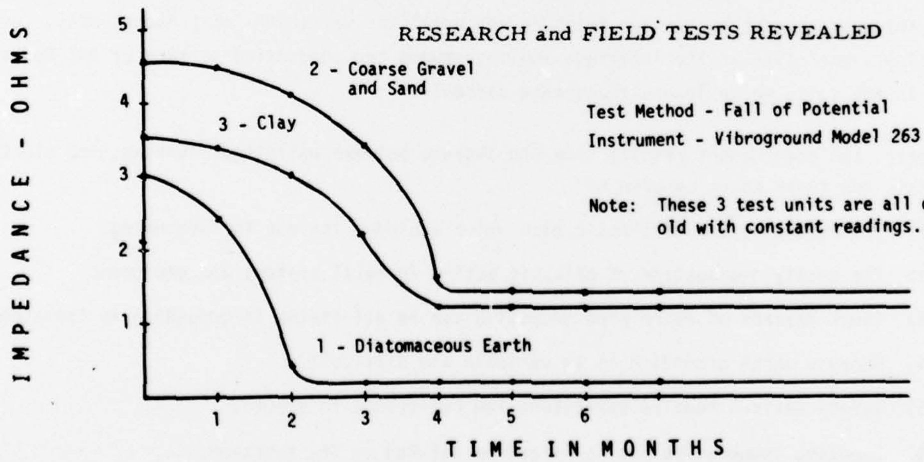
.K2-H Where bedrock is encountered too impervious for drilling with auger bit. Use this L shape horizontal model. Specify vertical depth requirement.

.K2-20 Is available in 20' length for power stations, microwave and communication towers, where there exists known earth resistance variables too great for good consistent communication. Also in areas where installations are vulnerable to lightning.

Note Resonant lengths for RF frequencies on special order.

Ground Clamp Tested For
#8 AWG Brass Cable Fastener
To
#3/0 AWG U-Bolt and Pressure Plate

UL Listed 467J



Patented U.S. #3,582,531, U.K. #1,343,182, Pending in Canada, Europe, and Asia.

78-50-5

XIT® ROD
GROUNDING DEVICES

P.O. Box 1314
Covina, California 91722
(714) 845-3986

Printed USA 745

FIGURE 5. XIT ROD TECHNICAL SPECIFICATION (SHEET 1 OF 2)

XIT ROD

Listed 467J

A HOLLOW-TUBE, CHEMICALLY-CHARGED-ROD ELECTRODE

On October 6, 1972 acceptance for Underwriters' Laboratories Listing was granted under UL467J and on January 30, 1974 the Electrical Council of Underwriters' Laboratories Inc., adopted Revisions of the Standard for Grounding and Bonding Equipment, in Appendix A, paragraphs 6.7L, 6.7M, and 6.7N exclusively covering the patented Xit Rod system, and which is now eligible for inclusion in the Revised National Electrical Code. Approval as an American National Standard has been established under ANSI-C33.8 effective April 24, 1974

SPECIAL FEATURES

Grounding in earth is variable by (1) soil type, (2) chemical content, (3) moisture, and since the size and depth of Xit Rod is compatible for good grounding, it also overcomes the three variables above by generating its own moisture and metallic salts and, most importantly, uses the resulting electrolyte as the interface medium between the conducting surface of Xit Rod and outwardly in the soil, which lowers resistance markedly.

Its conception and development results from the impasse between building, plumbing, and electrical officials and their codes because of:

1) The expanding use of plastic pipe which excludes its use for grounding.
2) The costly degradation of galvanic action in metal systems and equipment.
3) Shock hazards of water pipe grounding can be eliminated if grounding is isolated.
4) Because earth grounding is so variable and difficult.
5) Safety devices require consistent low resistance to ground.
6) Freezing temperature has no effect on Xit-Rod or its function.
7) Xit-Rod functions indoors or out.
8) Brazing directly to Xit-Rod is not harmful, although it may dry out and cause a short delay in elecrolyte formation in that portion of rod heated.

78-50-5

AS THE FINEST MADE SYSTEM AVAILABLE. IT IS TRULY THE MOST NEGATIVE APPROACH TO GROUNDING

FIGURE 5. XIT ROD TECHNICAL SPECIFICATION (SHEET 2 OF 2)

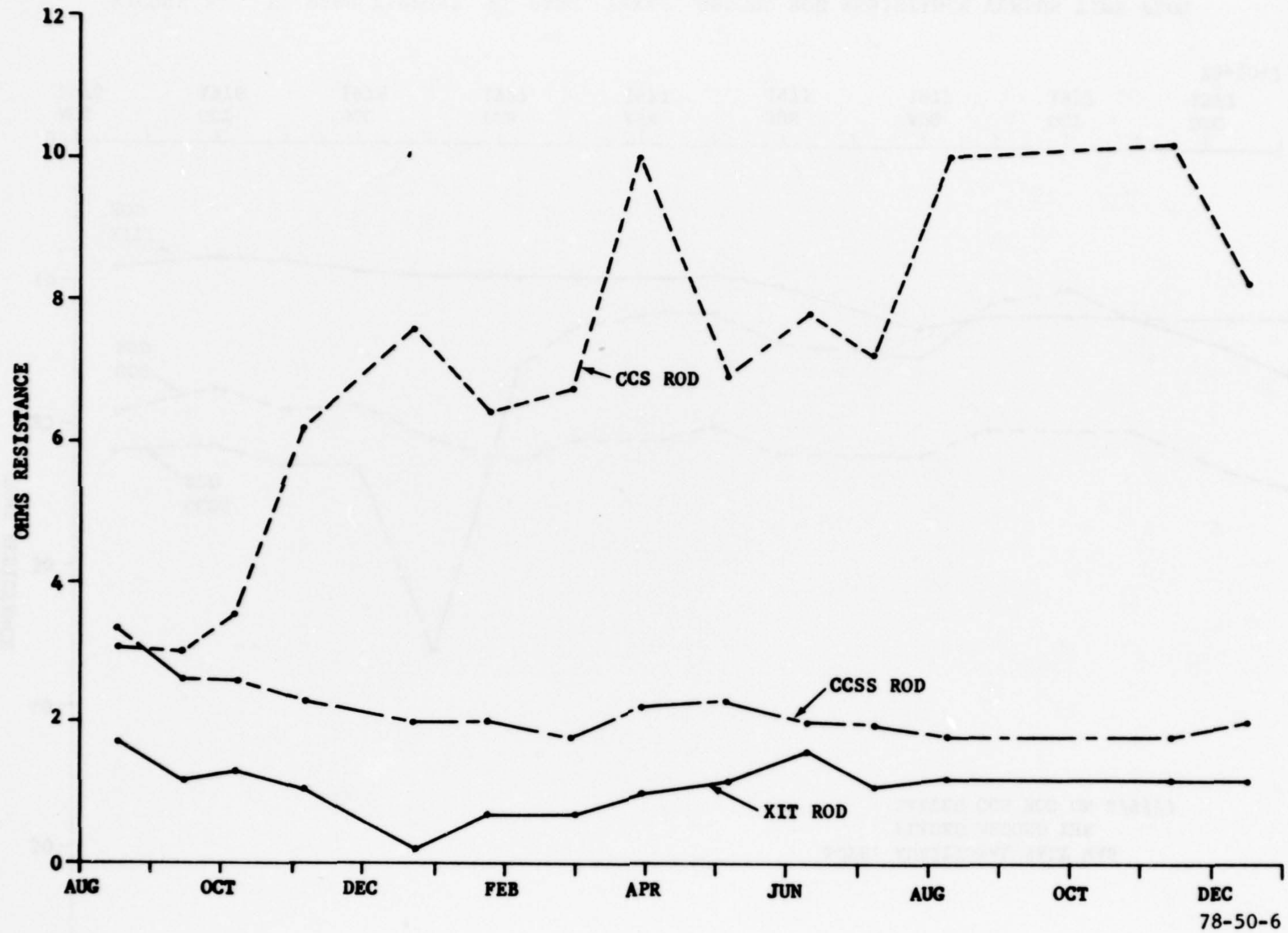


FIGURE 6. JEFFERSON COUNTY AIRPORT, BEAUMONT, TEXAS, GROUND ROD RESISTANCE VERSUS TIME PLOT

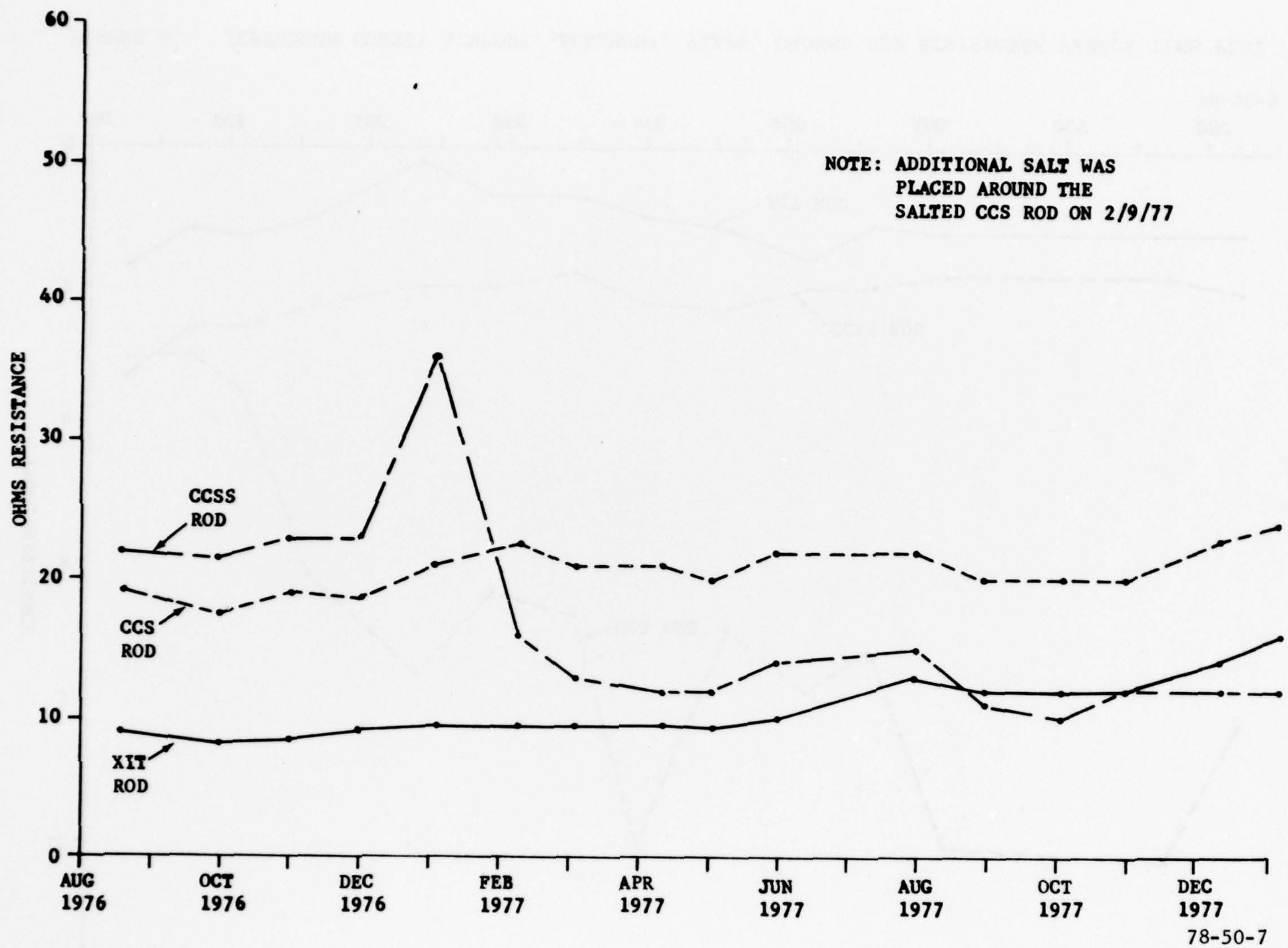


FIGURE 7. EL PASO AIRPORT, EL PASO, TEXAS, GROUND ROD RESISTANCE VERSUS TIME PLOT

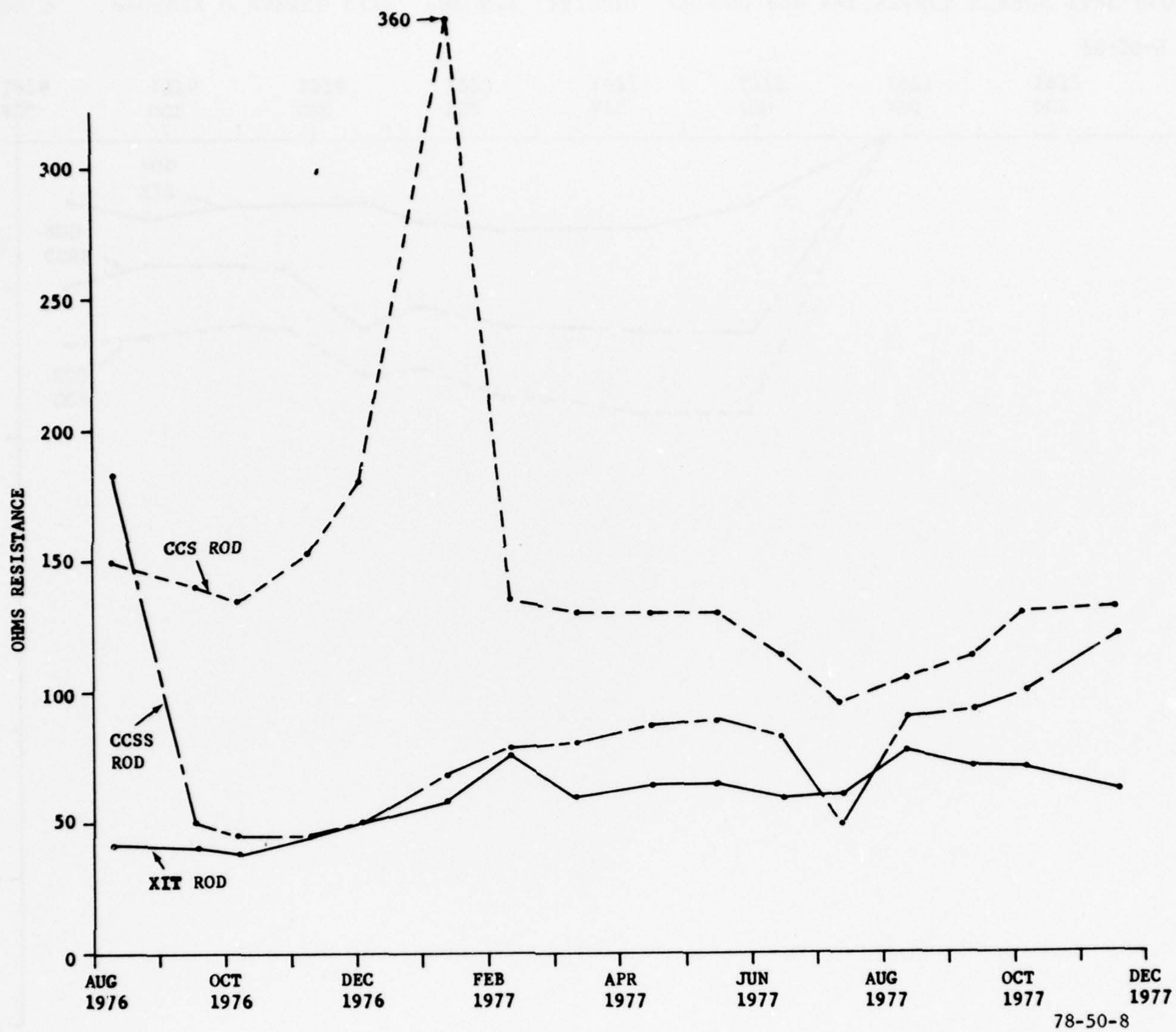


FIGURE 8. WILDWOOD RCAG SITE, WILDWOOD, NEW JERSEY, GROUND ROD RESISTANCE VERSUS TIME PLOT

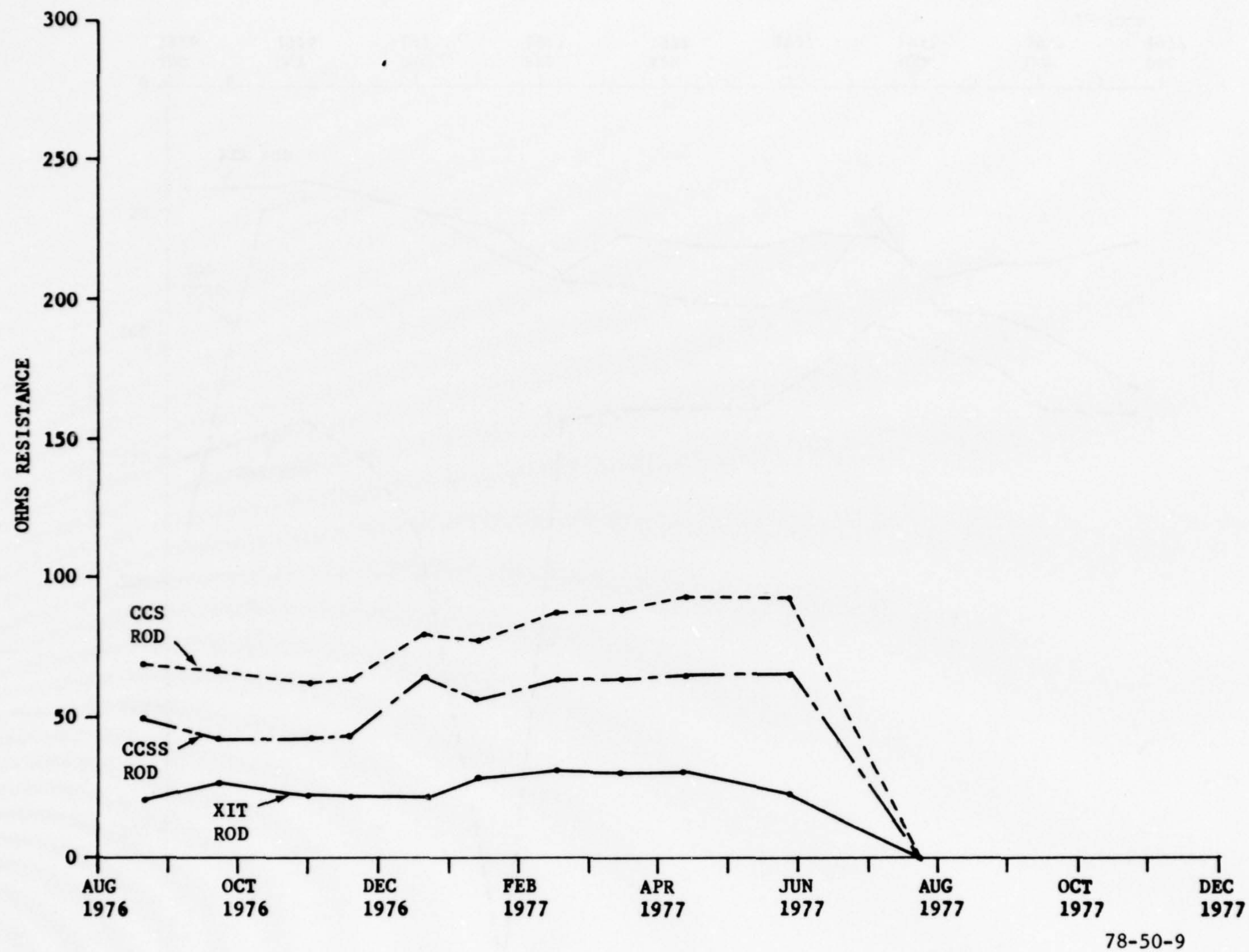


FIGURE 9. PHOENIX H MARKER SITE, PHEONIX, ARIZONA, GROUND ROD RESISTANCE VERSUS TIME PLOT

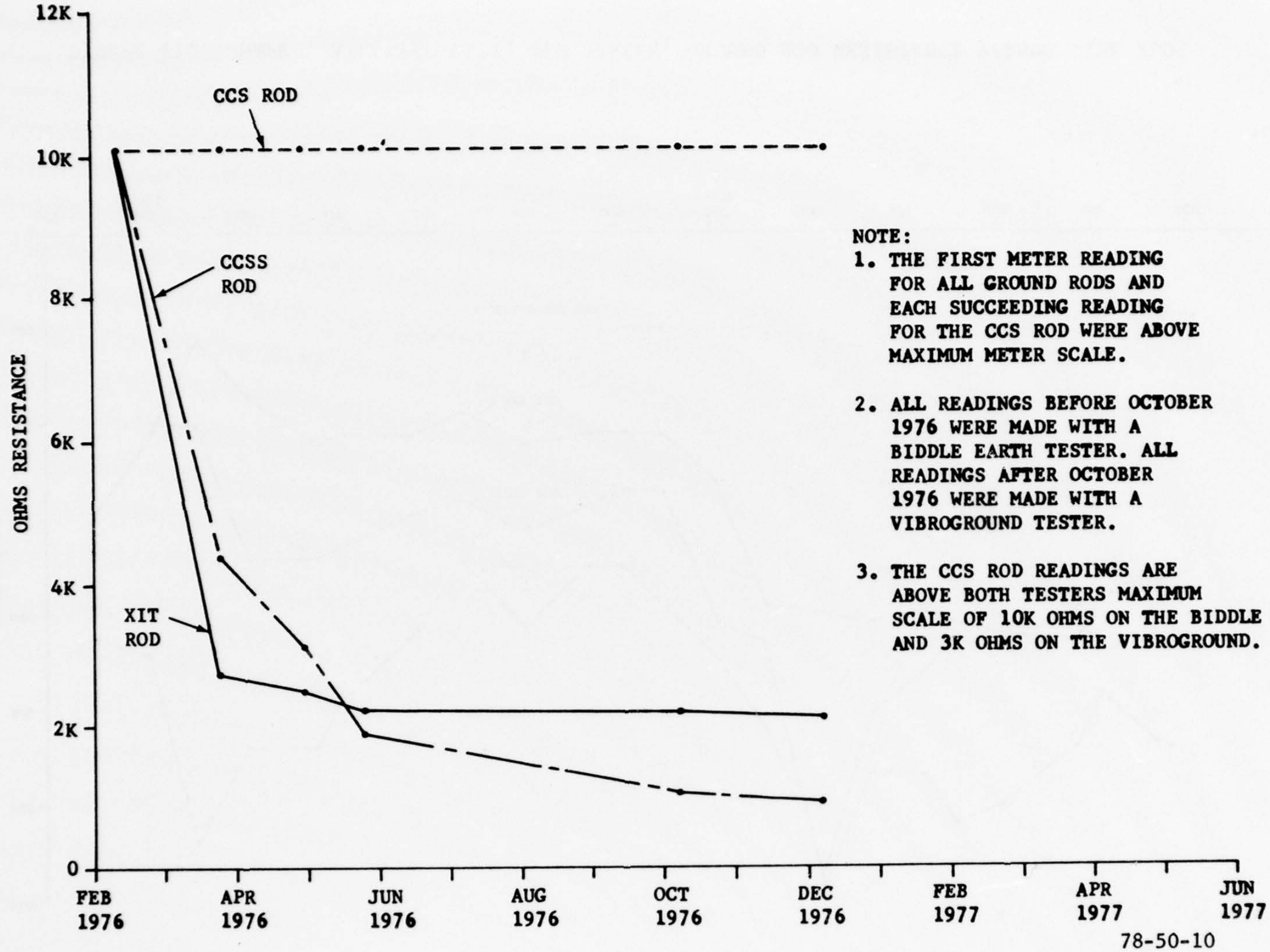
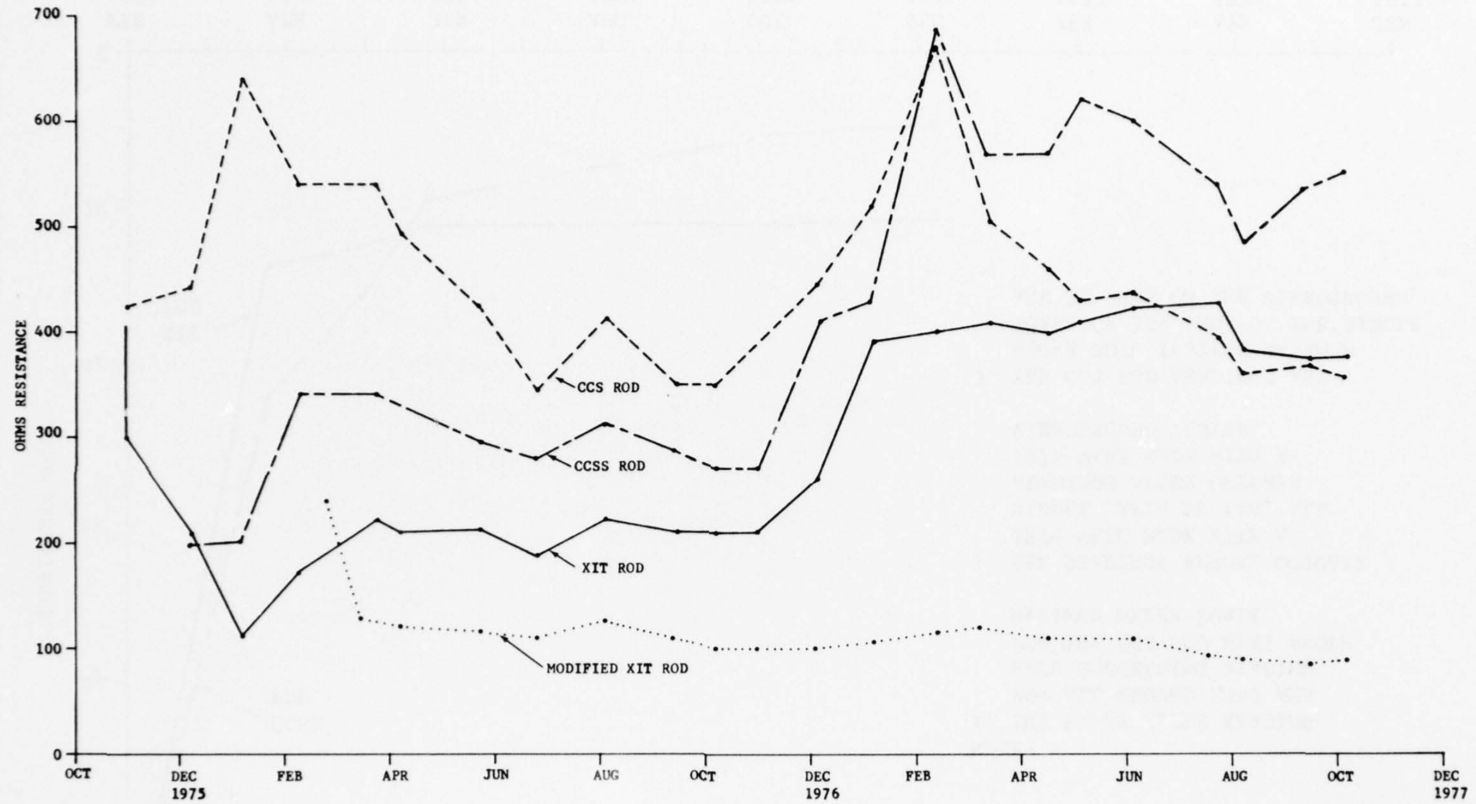


FIGURE 10. CHESTERFIELD VOR SITE, CHESTERFIELD, SOUTH CAROLINA, GROUND ROD RESISTANCE VERSUS TIME PLOT



78-50-11

FIGURE 11. NAFEC, ATLANTIC CITY, NEW JERSEY, GROUND ROD RESISTANCE VERSUS TIME PLOT

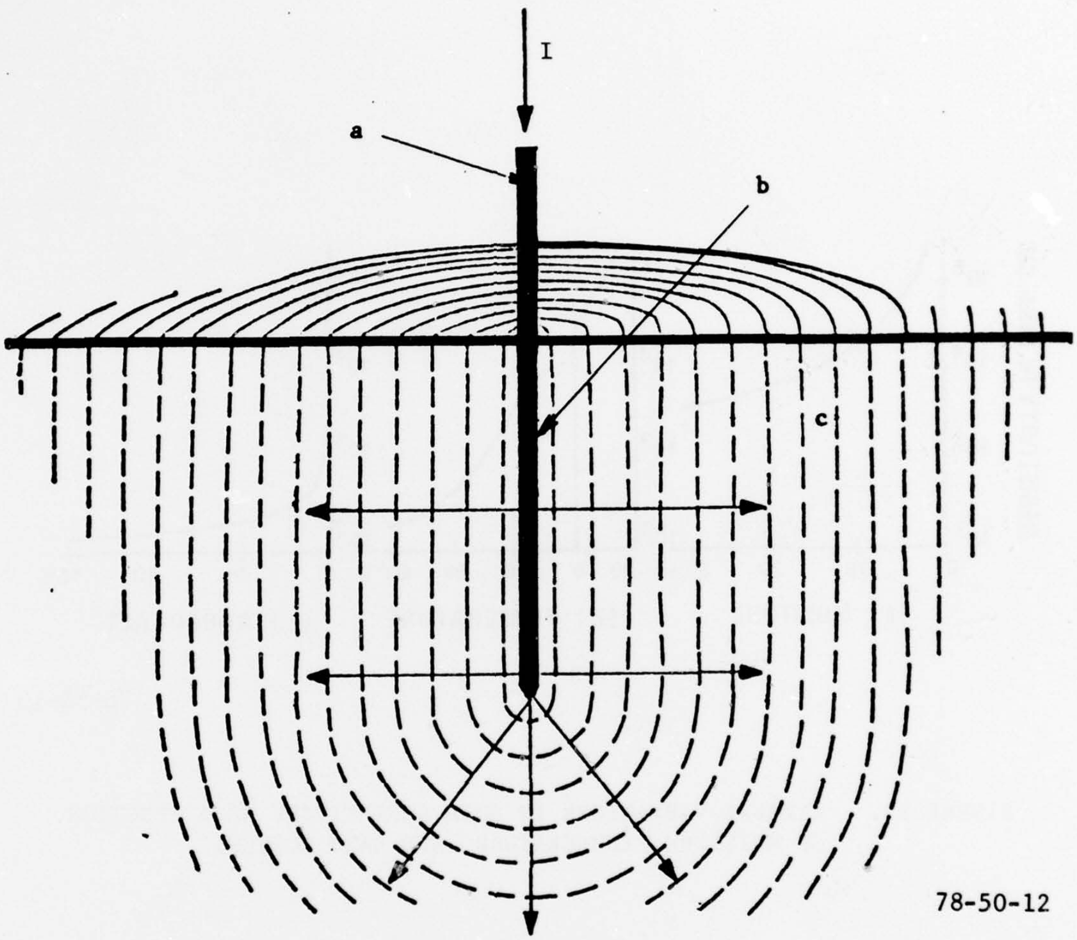


FIGURE 12. EARTH RESISTANCE SHELLS SURROUNDING A VERTICAL EARTH ELECTRODE

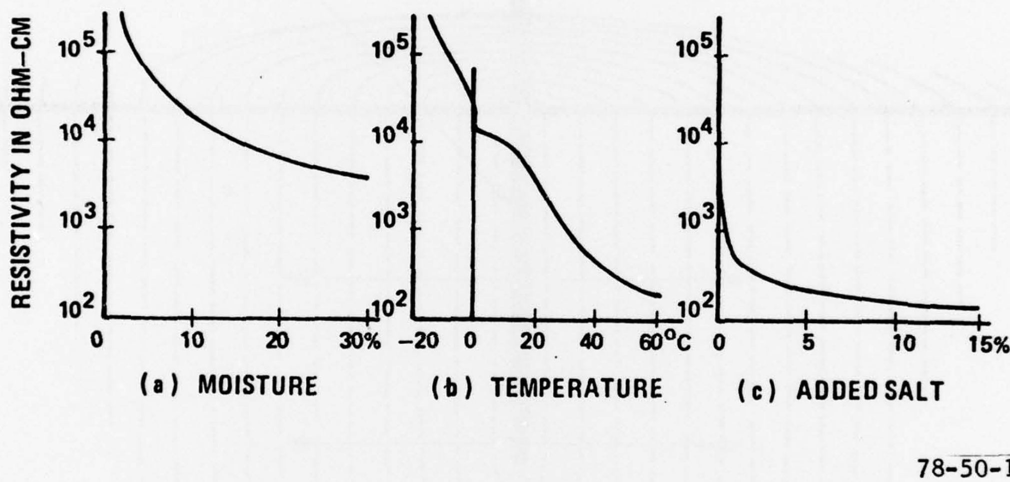


FIGURE 13. TYPICAL VARIATIONS IN SOIL RESISTIVITY AS A FUNCTION OF MOISTURE, TEMPERATURE, AND SALT CONTENT

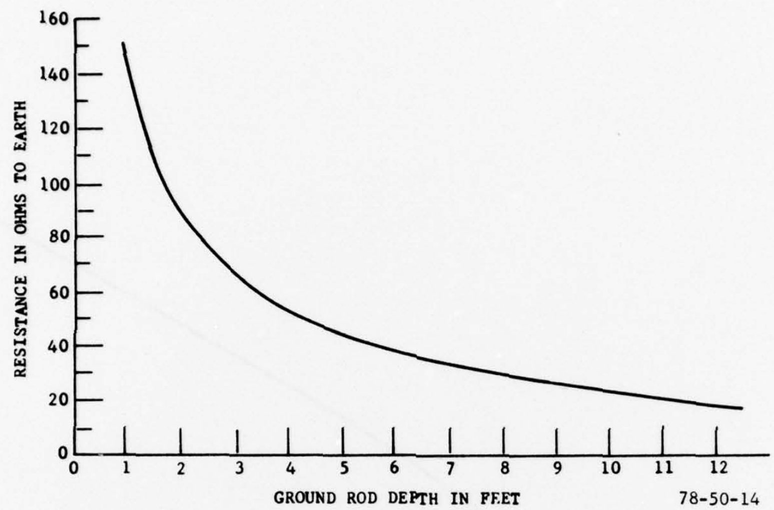


FIGURE 14. EFFECT OF ROD LENGTH UPON RESISTANCE

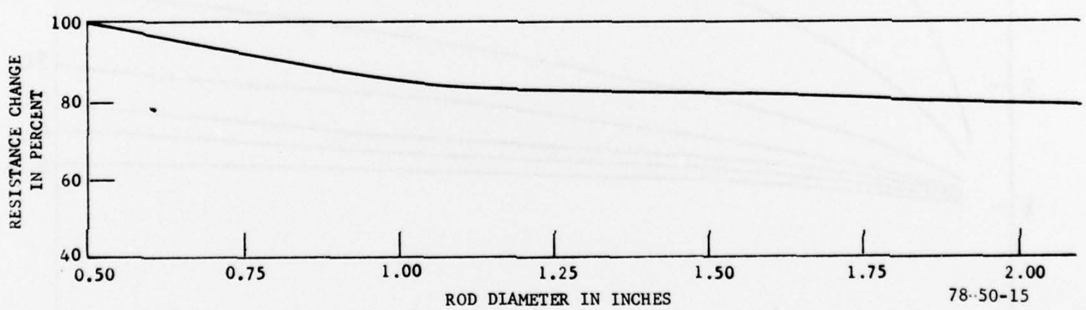


FIGURE 15. EFFECT OF ROD DIAMETER UPON RESISTANCE

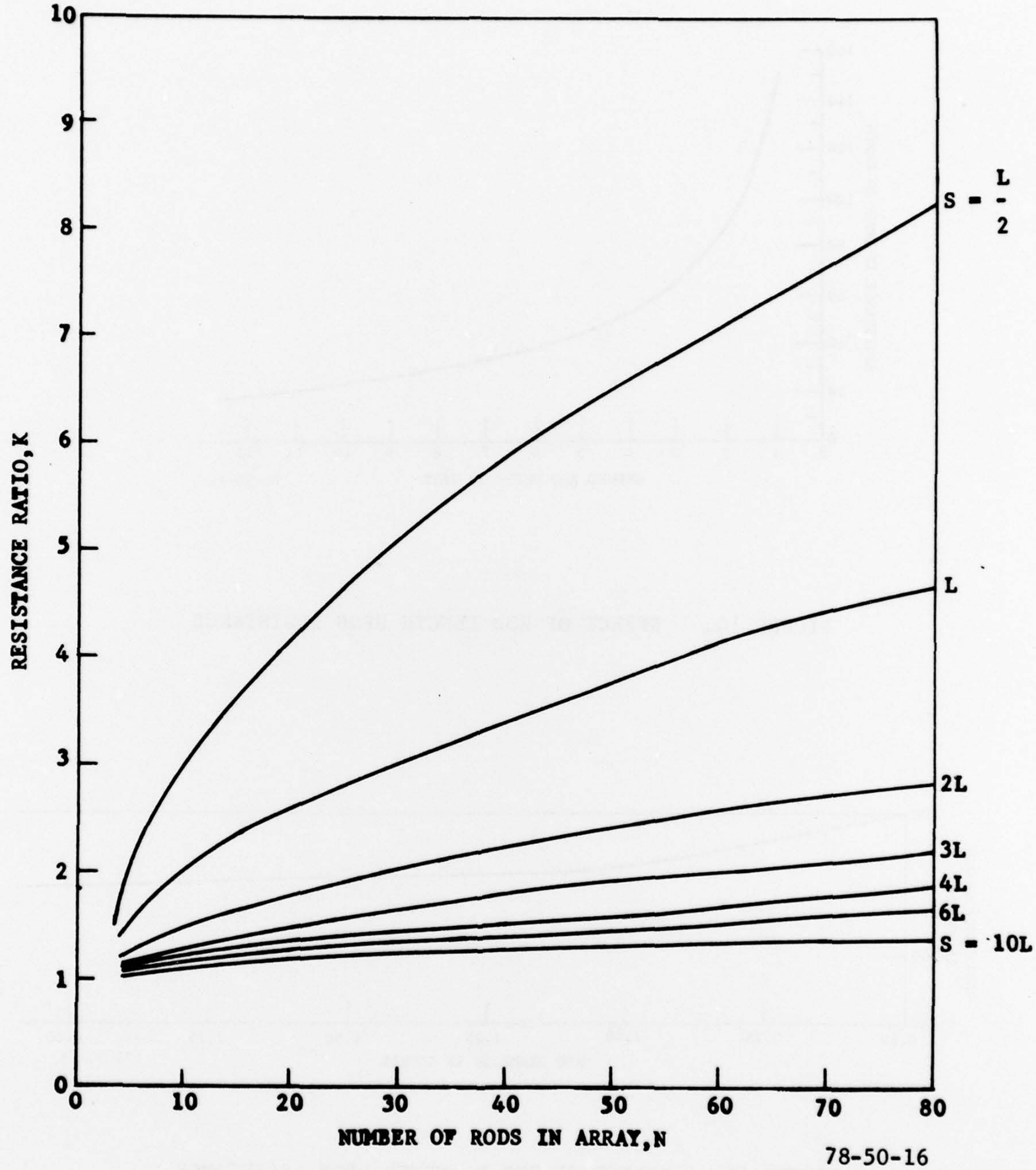


FIGURE 16. RATIO OF THE ACTUAL RESISTANCE OF A ROD ARRAY TO THE IDEAL RESISTANCE OF N RODS IN PARALLEL

TABLE A-1. PROGRAMMING PROCEDURE

LOC	CODE	KEY	COMMENTS
0	76	LBL	
1	11	A	ρ
2	42	STO	
3	01	01	
4	92	RTN	
5	76	LBL	
6	12	B	A
7	42	STO	
8	02	02	
9	92	RTN	
10	76	LBL	
11	13	C	L_W
12	42	STO	
13	03	03	
14	92	RTN	
15	76	LBL	
16	14	D	L_R
17	42	STO	
18	04	04	
19	92	RTN	
20	76	LBL	
21	15	E	d_R
22	42	STO	
23	05	05	
24	92	RTN	
25	76	LBL	
26	16	A'	K
27	42	STO	
28	06	06	
29	92	RTN	
30	76	LBL	
31	17	B'	N
32	42	STO	
33	07	07	
34	92	RTN	
35	76	LBL	
36	24	CE	R_T
37	53	(	
38	71	SBR	
39	38	SIN	R_W
40	65	X	
41	71	SBR	
42	39	COS	R_R
43	75	-	
44	71	SBR	
45	30	TAN	R_{WR}
46	33	X^2	
47	54	)	
48	55		
49	53	(	
50	71	SBR	R_R
51	38	SIN	
52	85	+	
53	71	SBR	
54	39	COS	R_W

LOC	CODE	KEY	COMMENTS
55	75	-	
56	02	2	
57	65	X	
58	71	SBR	
59	30	TAN	R_{WR}
60	54	)	
61	95	=	
62	92	RTN	
63	68	NOP	
64	76	LBL	
65	38	SIN	R_W
66	53	(	
67	53	(	
68	53	(	
69	53	(	
70	04	4	
71	65	X	
72	43	RCL	
73	02	02	A
74	55	÷	
75	89	π	
76	54	)	
77	34	$\sqrt{X}$	
78	65	X	
79	02	2	
80	54	)	
81	35	1/X	
82	85	+	
83	53	(	
84	43	RCL	
85	03	03	L_W
86	65	X	
87	93	.	
88	03	3	
89	00	0	meters
90	04	4	
91	08	8	
92	54	)	
93	35	1/X	
94	54	)	
95	65	X	
96	43	RCL	
97	01	01	ρ
98	54	)	
99	42	STO	
100	08	8	
101	92	RTN	
102	68	NOP	
103	76	LBL	
104	39	COS	R_R
105	53	(	
106	53	(	
107	53	(	
108	03	3	
109	65	X	

LOC	CODE	KEY	COMMENTS
110	43	RCL	
111	04	04	L_R
112	65	X	
113	01	1	inches
114	02	2	
115	55	÷	
116	43	RCL	
117	05	05	d_R
118	54	)	
119	28	LOG	
120	65	X	
121	93	.	
122	03	3	
123	06	6	
124	06	6	
125	65	X	
126	43	RCL	
127	06	06	K
128	54	)	
129	55	÷	
130	43	RCL	
131	04	04	L_R
132	55	÷	
133	43	RCL	
134	07	07	N
135	55	÷	
136	93	.	
137	03	3	
138	00	0	meters
139	04	4	
140	08	8	
141	65	X	
142	43	RCL	
143	01	01	ρ
144	54	)	
145	42	STO	
146	09	09	
147	92	RTN	
148	68	NOP	
149	76	LBL	
150	30	TAN	R_{WR}
151	53	(	
152	53	(	
153	53	(	
154	02	2	
155	65	X	
156	43	RCL	
157	03	03	L_W
158	55	÷	
159	43	RCL	
160	04	04	L_R
161	54	)	
162	28	LOG	
163	65	X	
164	93	.	

LOC	CODE	KEY	COMMENTS
165	07	7	
166	03	3	
167	54	)	
168	55	÷	
169	43	RCL	
170	03	03	L_W
171	55	÷	
172	93	.	
173	03	3	
174	0	0	meters
175	04	4	
176	08	8	
177	65	X	
178	43	RCL	
179	01	01	ρ
180	54	)	
181	42	STO	
182	10	10	
183	92	RTN	

PROGRAM DESCRIPTION

$R_T = (R_W R_R - R_{WR}^2)/(R R_R 2 R_{WR})$ Total Ground Grid Resistance

$R_W = (\rho/2\sqrt{4A/\pi} + \rho/L_W$ Total Connecting Wire Resistance

$R_R = (.366\,\rho\,K/L_R N)\,\log(3L_R/d_R)$ Total Rods Resistance

$R_{WR} = (.73\,\rho/L_W)\,\log(2L_W/L_R)$ Mutual Wire and Rods Resistance

USER INSTRUCTIONS

Step	Procedure	Enter	Press			Display
1	ρ = Soil Resistivity in meter-ohms	ρ value	A			ρ
2	A = Area of ground grid in feet	A value	B			A
3	L_W = Total length of wire used in feet	L_W value	C			L_W
4	L_R = Rod Length in feet	L_R value	D			L_R
5	d_R = Rod diameter in inches	d_R value	E			d_R
6	K = Resistance ratio	K value	2nd	A'		K
7	N = Number of ground rods	N value	2nd	B'		N
8	R_W = Total connecting wire resistance		SBR	2nd	Sin	R_W
9	R_R = Total Rods resistance		SBR	2nd	Cos	R_R
10	R_{WR} = Mutual wire and rods resistance		SBR	2nd	Tan	R_{WR}
11	R_T = Total ground grid resistance		SBR	CE		R_T

USER DEFINED KEYS

A	ρ
B	A
C	L_W
D	L_R
E	d_R
A'	K
B'	N

DATA REGISTERS

0			
1	ρ	6	K
2	A	7	N
3	L_W	8	R_W
4	L_R	9	R_R
5	d_R	10	R_{WR}